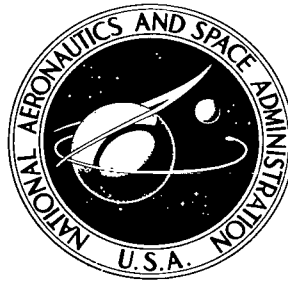


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EFFECT OF SOLAR ACTIVITY ON THE FREQUENCY OF FUNCTIONAL LEUKOPENIAS AND RELATIVE LYMPHOCYTOSES

by N. A. Shul'ts

*Academy of Medical Sciences USSR
Moscow, 1967*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • FEBRUARY 1970



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By N. A. Shul'ts

Translation of "O vliyani solnechnoy aktivnosti na chastotu funktsional'nykh
leykopeniy i otnositel'nykh limfotsitov." Summary Report.
Academy of Medical Sciences USSR, Moscow, 1967

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EFFECT OF SOLAR ACTIVITY ON THE FREQUENCY OF FUNCTIONAL LEUKOPENIAS AND RELATIVE LYMPHOCYTOSES

N. A. Shul'ts
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NATURE OF THE PROBLEM

Having regard to the importance of effects of the Sun's active radiation on the biosphere, the author has investigated the influence of solar activity on fluctuations in the leukocyte count in the circulating blood under nonpathological conditions.

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REASONS FOR STUDYING THIS PROBLEM

The progressive increase in the number of functional leukopenias accompanied by relative lymphocytoses at the end of the first World War, which coincided with a peak of solar activity, led the author to consider that changes in the blood picture may be dependent on fluctuations in solar radiation.

PUBLISHED DATA PRECEDING THE AUTHOR'S INVESTIGATION

The medical literature of that period provided no answer to the question, so that attention had to be directed to related biological disciplines, which by that time had discovered the existence of links between the sun and earth in the biosphere.

The author spent 35 years collecting and analyzing his material. His investigations of solar-terrestrial relationships enabled him to establish scientific contact with workers investigating this problem, and particularly with Russian scientists who first discovered the biological indicators of solar activity.

In 1892, F. N. Shvedov, when investigating the thickness of the annular rings of trees, discovered an 11-year solar rhythm in the character of their alternation. This problem was subsequently investigated in detail by Douglass and his school. The work of Clough was published in the 1920's, and this was followed by that of I. V. Maksimov, who demonstrated the presence of a 600-year solar cycle in the alternation of tree rings.

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In 1911, M. Ye. Tkachenko analyzed the ages of mixed pine and spruce forests in Arkhangel'sk Province and found that the years of formation of these forests coincided with Brueckner's cycles, connected with the secular solar cycles.

From a study of material in Voronezh and neighboring regions, M. P. Skryabin established the presence of a secular solar cycle in many of the phenomena of forestry: conditions in the pine fens, the growth of the pine and oak, the succession of species of trees, and so on. The work of V. R. Vil'yams, B. S. Gurevich, I. A. Benediktov and others studying the responsibility of the sun for catastrophic

* Numbers in the margin indicate pagination in the foreign text.

droughts in the USSR revealed a certain rhythm of drought conditions, coinciding with solar cycles.

A relationship between fluctuations in the population of certain large-scale agricultural pests and fluctuation in solar activity was demonstrated by N. S. Shcherbinovskiy, I. Ya. Polyakov, K. A. Satunin, Turkin, K. N. Rossikov, Severnov, Silant'yev, Vinogradov, I. G. Ioff, and many others.

Obvious traces of an 11-year solar cycle were found in a number of important life processes in fish by A. N. Derzhavin, P. Yu. Shmidt, M. A. Fortunatov, G. V. Nikol'skiy, and others.

The first studies by medical investigators of the influence of solar activity on the human organism only began to appear in the middle of the 1930s.

In 1934, T. and B. Düll demonstrated the absolute synchronism of mortality from tuberculosis and solar flares. In 1936-1938 they published the results of their numerous investigations into the effect of solar activity on mental function and mortality.

In 1935 Puig showed that geomagnetic storms produced by bursts of solar activity have an influence on lung hemorrhages in patients with tuberculosis.

B. de Rudder, in 1938, reported that according to his observations the incidence of cerebrospinal meningitis is dependent on the appearance of sunspots.

The International Society of Biological Rhythms, concerned with periodic fluctuations of physical phenomena in nature, was organized in Stockholm in 1937. The members of this society, through close mutual contacts, placed a wide interpretation on the problem of the influence of cosmic factors on the biosphere. As a member of this society, the author was able to engage in extensive consultation both with medical scientists and with specialists in allied disciplines working in different geographic districts. In this way a more profound study of the influence of solar activity on the blood system was possible. /5

After organization of the Society of Biological Rhythms, the number of persons studying the effect of active solar radiation on the human body began to grow rapidly. In 1942, E. Bach and L. Schluck stated that the incidence of eclampsia and pre-eclampsia is dependent on geomagnetic disturbances associated with fluctuations in solar radiation. Their observations were confirmed by H. Berg.

In the same year, R. and G. Reimann-Hunziker showed that the incidence of pulmonary embolism is dependent on fluctuations in solar activity. In 1953, H. Berg revealed that fluctuations in the number of cases of pulmonary embolism found at 836 autopsies performed at 13 institutes of pathology coincide with fluctuations in solar radiation.

In 1952, R. Reiter, analyzing 130,000 cases, demonstrated conclusively that solar flares influence the incidence of road traffic accidents, and showed experimentally that at a time of solar flares a person's reaction to a red traffic signal is almost four times slower.

In 1952, R. Martini showed absolute coincidence in the time of accidents in coal mines and fluctuations in solar radiation.

In 1957, F. Vering demonstrated the effect of active solar radiation on growth of staphylococci and Escherichia coli.

In 1959, M. Poumailloux and M. Viart, and in 1960, A. Giordano established a relationship between the incidence of myocardial infarction and fluctuations in solar activity.

In his dissertation, the author cites 130 sources from the literature, representing only a part of the tremendous number of papers devoted to solar-terrestrial connections in biology and medicine. He has mentioned only those investigations which have become widely known and which he cites frequently.

Czechoslovak scientists have made extensive studies of the influence of solar activity on the human organism. In 1958, D. Matousek and R. Barcal analyzed 18,296 deaths in Plzen region and found an exceptionally high mortality on the third day after strong solar flares, especially in years preceding a minimum of solar activity. In a period of increased solar activity they found a definite correlation between the mortality and the number of strong solar flares.

In the 1950s, clinical observations were supplemented by physico-chemical investigations by the well-known Italian scientist G. Piccardi, who demonstrated conclusively that active solar radiation can influence colloid systems. Very valuable research in this respect was carried out by M. Takata, T. Murasugi, O. Burkard, U. Becker, G. Caroli, and H. Filk. Since the blood is a colloidal system, the author established close contact with Professor G. Piccardi for the sake of mutual consultation and joint investigation of particular problems.

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Although carefully watching the periodical literature, both Soviet and non-Soviet, until the publication of his own researches into the influence of solar activity on the cell composition of the blood, the author found no reference to this problem. Priority in this matter thus belonged to the Soviet Union, as is acknowledged by the press both in the Soviet Union and elsewhere.

MATERIALS AND METHOD

The effect of solar activity on the cell composition of the blood could be studied either experimentally or statistically, on the basis of a large number of observations.

Inability to screen a group of subjects from cosmic influences for long periods compelled the adoption of statistical methods of investigation.

The author attempted to collect as much data as possible, because the use of a large number enables relationships to be detected which would be impossible with a small number of observations. By using the law of large numbers statistical indices could be freed from the effect of random circumstances, and in this way the action of objective principles could be revealed in the mass of studied phenomena.

A smaller number of observations would have sufficed had they been carried out in accordance with strict statistical requirements, but since in some places, especially far out on the periphery, physicians are inadequately acquainted with the theory and methods of statistical research, the number of observations had to be increased.

While writing his dissertation, the author collected 336,177 cases, of which 153,370 were collected in the area of Greater Sochi (435 persons were included twice, accounting for 0.2%). The number of subjects included 77,415 males and 75,955 females. Their ages ranged from 20 to 60 years. No special consideration was paid to their ages, because the author was interested in the question of the action of active solar radiation on the cell composition of adult human blood under nonpathological conditions, and not in the selective ability of different age groups to tolerate fluctuations in solar radiation.

Solar activity is not always and everywhere manifested identically, and as Clayton and V. B. Shostakovich have shown, in different geographic districts people respond differently to the same phase of solar activity. In this connection, the author, in conjunction with a team of hematologists belonging to the Sochi Health Resort Administration, investigated fluctuations in the leukocyte count during the 19th solar cycle in vacationers coming from different geographic districts, and also established close contacts with clinical laboratories located at different latitudes and longitudes of the Soviet Union. This enabled him to compare data on inhabitants of the Arctic region with data on inhabitants of the subtropics, and to compare data on inhabitants of the Pacific coast with data on inhabitants of the Baltic region, and so on (Table 1). /7

The zone of the observations was very soon widened still further by the inclusion of foreign countries, thus enabling the principles determining the effect of geographic latitude of the locality on the leukocyte count under non-pathological conditions to be established.

In the north the percentage of leukopenia was higher than in the south. /8

Blood was taken from all subjects under the same conditions: in the morning, before taking food, in a sitting position in order to exclude the influence of taking food, physical exertion, changes in the position of the body, and so on.

Although all cases were excluded when factors were present which usually produce leukopenia or lymphocytosis, the author admits that among the subjects there might nevertheless have been some in whom the leukopenia and lymphocytosis could be due to undetected diseases, the taking of drugs, or other reasons causing leukopenia or lymphocytosis. However, their number must have been too small to have any appreciable effect on the data obtained, because data from hospitals and polyclinics was considered separately. /9

Blood was investigated from persons of both sexes, staying in sanatoria and rest homes. Because of its special properties, no blood was considered from children and elderly persons.

TABLE 1. CITIES FROM WHICH THE AUTHOR OBTAINED INFORMATION CONCERNING FUNCTIONAL LEUKOPENIAS AND RELATIVE LYMPHOCYTOSES

Latitude	City	Country	Latitude	City	Country
70°N	Noril'sk	RSFSR	45°N	Grenoble	France
69°N	Murmansk	RSFSR	45°N	Kzyl-Orda	Kazakh SSR
68°N	Nar'yan-Mar	RSFSR	45°N	Gelendzhik	RSFSR
63°N	Yagodnoye	RSFSR	44°N	Kislovodsk	RSFSR
62°N	Talaya	RSFSR	43°N	Sochi	RSFSR
61°N	Oslo	Norway	43°N	Monaco	Monaco
60°N	Leningrad	RSFSR	43°N	Florence	Italy
59°N	Magadan	RSFSR	43°N	Nice	France
57°N	Riga	Latvian SSR	43°N	Arles	France
54°N	Ul'yanovsk	RSFSR	43°N	Montpellier	France
53°N	Barnaul	RSFSR	42°N	Rome	Italy
52°N	Usol'ye	RSFSR	42°N	Chimkent	Kazakh SSR
51°N	London	England	31°N	Alexandria	Egypt
50°N	Louvain	Belgium	22°N	Calcutta	India
49°N	Paris	France	9°N	Addis-Ababa	Ethiopia
48°N	Debal'tsevo	Ukraine	6°N	Colombo	Ceylon
47°N	Gur'yev	Kazakh SSR	0°N		
47°N	Taganrog	RSFSR	6°S	Jakarta	Indonesia
46°N	Odessa	Ukraine	17°S	Papeate	Polynesia
45°N	Venice	Italy	38°S	Melbourne	Australia

During the period of the 16th (1921-1932) and 17th (1933-1941) solar cycles the author collected data mainly in the Ukraine; in the period of the 18th solar cycle (1941-1943) in the Arctic region of the Far North-East. In the course of the 19th solar cycle from 1954 through 1964, tests were carried out by a group of hematologists at 12 sanatoria in the city of Sochi and by the author's correspondents working in different geographic districts of the Soviet Union and abroad, who accurately reported their observations to him. The most complete and exhaustive information was that obtained during the 19th solar cycle (1954-1964), especially in the period of the International Geophysical Year (1957-1959). Correlation between the compared biological and solar phenomena is seen particularly clearly when the data for comparison are presented graphically. Properly composed diagrams and drawings give a better grasp of statistical data and facilitate its scientific analysis. Dynamic curves showing the development of the phenomena under study in time are most convenient in this respect.

To eliminate the influence of random variations on the numbers in a series and to establish the basic tendency of the dynamics of the phenomena, in some cases the author used a smoothing method.

TABLE 2. FOREIGN CENTERS WITH WHICH THE AUTHOR
ESTABLISHED SCIENTIFIC CONTACTS ON THE PROBLEM
OF SOLAR-TERRESTRIAL CONNECTION IN MEDICINE

City	Country	City	Country
Addis-Ababa	Ethiopia	Monpellier	France
Alexandria	Egypt	Montreal	Canada
Arles	France	Münster	West Germany
Bad Elster	East Germany	Nancy	France
Bologna	Italy	Nice	France
Brno	Czechoslovakia	New York	USA
Budapest	Hungary	Oslo	Norway
Venice	Italy	Pavia	Italy
The Hague	Holland	Paris	France
Genoa	Italy	Papeete	Tahiti (Polynesia)
Grenoble	France	Pasadena	USA
Jakarta	Indonesia	Pittsburgh	USA
Dresden	East Germany	Plzen	Czechoslovakia
Dublin	Eire	Prague	Czechoslovakia
Cairo	Egypt	Rome	Italy
Calcutta	India	Rostock	East Germany
Kiel	West Germany	San Juan	Puerto Rico
Colombo	Ceylon	Sofia	Bulgaria
Kumamoto	Japan	Istanbul	Turkey
Leipzig	East Germany	Stockholm	Sweden
London	England	Turin	Italy
Louvain	Belgium	Ferney Voltaire	France
Marseille	France	Ferrara	Italy
Meudon	France	Philadelphia	USA
Melbourne	Australia	Florence	Italy
Milan	Italy	Frankfurt-am-Main	West Germany
Modena	Italy	Zurich	Switzerland
Monaco	Monaco	Exeter	England

For investigation of solar-terrestrial connections in the biosphere, the method of comparison of curves is most demonstrative. In his published papers and lectures at conferences and congresses, the author therefore gave preference to graphs. The most convenient for these purposes are dynamic curves, smoothing, and the method of superposed epochs. These methods are also widely used by investigators outside the USSR, thus facilitating comparison of results obtained in different parts of the world. When comparing biological phenomena with the solar, which differ sharply from terrestrial, and statistical curves in the method of superposed epochs, widely used at the present time both by heliophysicists and medical scientists studying solar-terrestrial relationships, the author took into account only the right maximum R as the most stable maximum created by corpuscular streams from the most active regions of the sun.

Disturbance of the Leukocyte Count and of Equilibrium
Between Their Different Types

Of all the blood cells the leukocytes are most sensitive to fluctuations in solar radiation ("Toulouse medical," 1960, No. 10). Neutrophils react particularly clearly to an increase in solar activity, their number beginning to fall sharply, disturbing the leukocytic equilibrium in favor of the lymphocytes (Lab. Delo, 1960, No. 2, pp. 36-38). At a peak of solar activity, shifts of the neutrophils to the right were often observed. In some persons, with a sharply decreased leukocyte count, sometimes solitary giant hypersegmented neutrophils were observed. Occasionally evidence of hyperfragmentation of the nuclei and marked eosinophilia of the cytoplasm could be seen. These phenomena were particularly marked in enfeebled persons with vitamin C deficiency living in the Arctic region.

In some persons with a clearly defined picture of solar toxicosis, toxogenic granules were observed in the cytoplasm of the neutrophils, in the form of dust-like granules readily stained by Freifeld's method (Lab. Delo, 1960, No. 2, pp. 36-38).

During a prolonged increase in solar activity the number of basophils decreased (Lab. Delo, 1960, No. 2, pp. 36-38).

The absolute number of lymphocytes in persons with relative lymphocytosis (during functional leukopenias) fell. In a series of lymphocytes, cells with a narrow band of cytoplasm were predominant. Occasionally atypical forms were seen.

During a prolonged increase of solar activity, a monocytic reaction was sometimes observed in persons with functional leukopenia. No changes whatever were observed in the nuclei or cytoplasm of the monocytes.

So far as cells of the erythroid series are concerned, even at a peak of solar activity neither quantitative nor qualitative changes of any significance were observed (Lab. Delo, 1960, No. 2, pp. 36-38).

With respect to platelets, during an increase in solar activity a slight decrease in their number was observed and some atypical forms with an ill-defined granulomere appeared.

Synchronism of Phases of Functional Leukopenias and Relative
Lymphocytoses with Fluctuations in Solar Activity

At the beginning of the present secular solar cycle, before the beginning of World War I, the normal leukocyte count was regarded as $6000-8000/\text{cm}^3$ blood.

At the peak of this cycle (1957-1958) the lower limit of normal was taken to be 5000. In the city of Noril'sk in July, 1957, after a strong solar flare

(class e+) the number of functional leukopenias with a leukocyte count below 5000 was 42%. In the city of Sochi in 1950, the number of leukopenias with a leukocyte count below 4000 was 2.7% (solar index $W = 84$), and in 1957 it was 7.6% (in this case the solar index W reached the figure of 190 for the first time in 200 years). The leukocyte count at the crest of the secular solar cycle in clinically healthy persons frequently fell to 3000 and below (Lab. Delo, 1960, No. 2).

The percentage of lymphocytes before the first Imperialist War was normally 25. At the peak of the secular solar cycle, under nonpathological conditions, a lymphocyte percentage of 75 was by no means rare (Lab. Delo, 1960, No. 2).

Analysis of the collected data and their comparison with solar indices revealed synchronism of phases of the fluctuations in the number of functional leukopenias and relative lymphocytoses with the indices of solar activity (Sol-nechnyye Dannyye, Akad. Nauk SSSR, 1960, No. 7, pp. 82-85). The leukocyte count both absolute and differential, was found to be affected not only by the age, occupation, nutritional status, disease, therapeutic substances, and so on, but also by changes in solar radiation (Lab. Delo, 1963, No. 10, pp. 3-7).

Changes in the composition of the leukocyte in the blood take place in cycles, in phase with the course of the indices of solar activity, as independent processes over a given time interval, and they cannot be reduced to a system of strictly sinusoidal (harmonic) components (Lab. Delo, 1963, No. 10, pp. 3-7).

Influence of Local Geographic Conditions on Composition of the Blood Leukocytes under Nonpathological Conditions

The author established that the incidence of functional leukopenias and relative lymphocytoses in the same time intervals differs in different geographic districts and is related to the latitude of the locality. It increases in a northerly direction and decreases toward the South (Lab. Delo, 1963, No. 10, pp. 3-7).

At the peak of the secular solar cycle, when an exceptionally high percentage of functional leukopenias and relative lymphocytoses was observed in Europe, the author received reports from Central Africa, India, Indonesia, and Polynesia to the effect that the leukocyte count in healthy subjects remained normal within the old normal limits suggested by Victor Schilling. This phenomenon of dependence of the leukocyte composition of the blood on geographic latitude of the locality, first described by the author, requires further study (Problemy gematologii i perelivaniya krovi, 1963, No. 3, pp. 20-26). Since the latitude of a place influences fluctuations in the leukocyte count, it must be taken into consideration when the results of blood examinations are analyzed (Folia Haematologica, Leipzig, 1962, 79, No. 4, 401-417).

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Because of these cyclic changes in the absolute and differential leukocyte counts, the concept of absolute and static normal values of these indices is meaningless. Normality of the cell composition of the blood is a relative concept, and as well as making allowance for differences due to age and sex, it must also take into account the local geographical conditions and significant fluctuations in active radiation from the sun (Lab. Delo, 1963, No. 10, 3-7).

Leukocyte Tests of Solar Activity

The discovery that fluctuations in the leukocyte count coincide with fluctuations in indices of solar activity led to the conclusion that functional leukopenias and relative lymphocytoses could serve as novel leukocyte tests of solar activity.

The author suggested three leukocyte tests: a) functional leukopenias, b) relative lymphocytoses, and c) a combined test of functional leukopenias and relative lymphocytoses.

This last test confirms the validity of I. A. Kassirskiy's concept that functional leukopenias and relative lymphocytoses are phenomena of the same order. This test has proved the most sensitive index of the effect of solar activity on the leukocyte count of the circulating blood under nonpathological conditions (Folia Haematologica, 1962, 79, No. 4, 401-417).

In a period of considerably increased solar activity, functional leukopenias were preceded by a transient leukocytosis (Lab. Delo, 1960, No. 2, 36-38).

Analysis of synchronization of the incidence of functional leukopenias and relative lymphocytoses with changes in solar radiation led one to consider leukocyte tests of solar activity sensitive biological indicators of the active radiation of the sun, frequently detecting the onset of active processes on the sun sooner than they /13 could be recorded by astronomical instruments (Problemy Gematologii, 1963, No. 3, 20-26).

At the beginning of the usual solar cycle the curve of functional leukopenias begins to rise before the curve of sunspots (Folia Haematologica, 1962, 79, No. 4, 401-417). Over the last 200 years the largest number of sunspots was recorded in 1957. In that same year the highest values of the leukocyte tests of solar activity were determined.

In 1958 a series of phenomena not hitherto observed were discovered on the sun. During the same year the leukocyte tests gave results accurately reflecting their course, terminating at the same time as the phenomena on the sun (Folia Haematologica, 1962, 72, No. 4, 401-417).

Forecasting the Incidence of Functional Leukopenias and Relative Lymphocytoses

The author's observations have shown that cyclic changes in the leukocyte count under nonpathological conditions are not connected with meteorological factors. Rainy or cold seasons produced no appreciable changes in the character of the curve of incidence of functional leukopenias and relative lymphocytoses compared with dry and warm seasons. The seasonal dynamics fully reflected the Corti effect and the solar hypothesis of Piccardi (Folia Haematologica, 1962, 79, No. 4, 401-417).

A. Ya. Bezrukova's suggestion that different solar indices operate at different phases of the 11-year cycle was confirmed by the author's observations (Zemlya vo vselennoy, The Earth in the Universe, Moscow, Mysl' Press, 1954, pp. 382-399). (Translator's note: Translation is available as NASA TT F-345.)

At the time of a peak of solar activity the author forecast a gradual return to a normal leukocyte count on the decremental part of the curve of solar activity. However, since this maximum belonged to a secular cycle, a low leukocytosis was possible for several years longer yet, in healthy persons, particularly living in the north (Lab. Delo, 1960, No. 2, 36-38). This prognosis was confirmed (Lab. Delo, 1963, No. 10, 3-7).

Feasibility of a Complex Study of Solar-Terrestrial Connections in Medicine

The author's observations have shown that the number of functional leukopenias rose unexpectedly sharply in the first half of 1960. A similar phenomenon was established by Piccardi with respect to fluctuations in his chemical tests. M. N. Gnevyshev discovered that in the first half of 1960 there was a second /14
peak of solar activity (the first was in 1957). This coincidence between the results of observations of haematologists, physical chemists and heliophysicists, once they had been correctly explained at the astronomical observatory, further emphasize the feasibility of the complex study of solar-terrestrial connections (the subject of the author's paper to the 12th International Medical Congress in Ferrara in May, 1965).

In February, 1960, at an All-Union Inter-Institute Conference of the Academy of Sciences of the USSR on the subject: Sun—Troposphere, the author described the results of his investigations of the influence of solar activity on the leukocyte picture of the blood under nonpathological conditions, thus establishing priority of the Soviet Union in this matter (Solnechnyye Dannyye, Akad. Nauk SSSR, 1960, No. 7, 82-85).

Discussion of Results

To ignore fluctuations in solar activity means to take account of the effect of only a small part of the solar spectrum on the body and to disregard the remaining and larger part of the electromagnetic waves and also corpuscular streams, whose influence on living processes is not always beneficial.

The high sensitivity of some organisms even to very slight fluctuations of solar activity and their selective ability present extensive opportunities for studying solar-terrestrial connections in biology and medicine. Investigations of direct effects of those geoactive components of solar radiation observed by the author, which cannot be felt abiologically, are particularly promising (Folia Haematologica, 1962, 79, No. 4, 401-417).

The problem whether rays of the solar spectrum not reaching the surface of the earth can nevertheless influence its biosphere has been answered by postulating that the different levels of the earth's atmosphere are physically interconnected, so that the whole of the earth's atmosphere constitutes a single physical entity. The active radiation of the sun, being geoactive, i. e., capable of being absorbed by the earth's atmosphere) physically modifies the "normal" state of this atmosphere. It is very important to note that with a change in visible solar activity, a redistribution of the spectrum of solar electromagnetic radiation takes

place. Radiation of the active sun differs qualitatively from radiation of the passive sun. Moreover, active areas of the sun also emit an additional quantity of corpuscles at above-parabolic velocity.

Cosmic radiation, now engaging the attention of medical scientists, also has its source in the active sun which in some respects regulates it. Since it consists to some extent of relativistic particles, unlike the usual nonrelativistic helio-corpuscles, it reaches the biosphere. A gigantic increase in solar activity led to unprecedented bursts of intensity of cosmic radiation. This was a subject studied in the International Geophysical Year. It is being studied by special earth satellites. Medical scientists cannot afford to ignore such currently important and promising fields.

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Short-wave ultraviolet rays, x-rays and nonrelativistic corpuscles do not reach the troposphere, yet the consequences of physical changes in the upper layers of the atmosphere due to active solar photons and corpuscles absorbed by the upper layers of the atmosphere nevertheless develop in the troposphere.

Recognition that many biological phenomena are due to the sun has been withheld only through insufficient acquaintance of most physicians with recent advances in heliogeophysics and by psychological inertia.

Although changes in the leukocyte count during fluctuations of solar activity observed by the author recall the response of the blood system to exposure to ionizing radiation, the transient leukocytoses and subsequent leukopenias which have been described are functional in origin. The author's data showed that persons with a normally low leukocyte count under nonpathological conditions had only a temporary functional depression of the bone marrow. In some persons this continued for several months, and in others for several years. Repeated blood tests on laboratory staff showed that the leukocyte count changed several times in the same persons in the course of solar cycles, falling in the years of maxima of solar activity and rising in the years of minima to a greater or lesser degree depending on the lability of the organism.

During exposure to ionizing radiation, hypoplasia develops, usually progressing to aplasia of the granulocytic system of the bone marrow with organic leukopenia. Fortunately the earth's atmosphere protects us against the harmful action of the sun's active radiation, and its indirect influence thus does not have the serious consequences which direct exposure to radiant energy (x-rays, radium, etc.) would have.

For hundreds of thousands of years the human body has become adapted to cyclic fluctuations in solar activity, and only when these fluctuations are exceptionally great does functional depression of granulopoiesis arise in some labile subjects. The toxogenic granules sometimes observed in the cytoplasm of neutrophils indicates lowering of the resistance of these cells.

Blood, being a colloidal system, is extremely sensitive to all types of external influence. The effects of the electric fields of the atmosphere, magnetic waves, cosmic radiation, solar flares, and the emission of radio waves from the sun on colloidal systems, discovered during periods of increased active solar

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radiation, as is clearly illustrated by material described in the author's dissertation (Solnechnyye Dannyye, Akad. Nauk SSSR, 1960, No. 9, 84-86).

The author does not discuss in detail the mechanism of action of active solar radiation on the blood system for the reason that this is not the subject of his dissertation. Many valuable monographs have been written on hematopoiesis and ionizing radiation, in which the mechanism of action of ionizing radiation on hematopoiesis is discussed. The author is concerned with the problem of coincidence between phases of changes in the leukocyte count under nonpathological conditions and fluctuations in active solar radiation as an indication of solar-terrestrial connections in the biosphere, a problem meriting attention because of its current importance and promising outlook.

The author's problem was to show that the leukocytes are an exceptionally sensitive indicator of fluctuations in solar radiation, marking a fresh advance in the study of solar-terrestrial connections in biology and medicine.

The increase in number of functional leukopenias and relative lymphocytoses observed by the author in northern latitudes is explained by the fact that the nearer one approaches the poles, the more strongly the effect of cosmic radiation and of corpuscular and magnetic disturbances is manifested (Annales Médicales de Nancy, 1963, pp. 822-827).

When analyzing the lymphocytoses of wartime and the period of famine in the 1920s, the author found that the solar index \bar{a} , discovered in 1940 by M. S. Eigenson, and dependent on the intensity of the sun's geoactive corpuscular radiation, was bimodal in those years. One peak took place in the years of the first Imperialist War, the second in the postwar famine period. Hence, the high lymphocytosis of the 1920s was just as much due to the sun as the subsequent and higher lymphocytoses observed, for example, in the period 1956-1958 (Problemy Gematologii, 1963, No. 3, 20-26).

In his dissertation the author cites statements made by many German, British, French, Belgian, Italian, Swedish, and other investigators explaining the sudden increase in the number of functional leukopenias and relative lymphocytoses during recent years as the consequences of the second World War, due to malnutrition, and to unexplained geographical and climatic influences.

By comparing results given by these workers with the course of solar indices, the author showed that all the changes which they describe in the blood picture took place in years of sharp increases of solar activity, and malnutrition as an explanation was invalidated by investigations by eminent specialists who discovered that the observed changes in the blood picture persisted despite a considerable improvement in nutrition (the solar activity continued to remain high during that period). References to the conclusions of some European investigators concerning unexplained consequences of the War (Brayton) are also invalid, because the above-mentioned changes in the blood picture were observed in the population during the years immediately preceding the War (A. Ferrier). The conclusions of German authors placing responsibility on the increase in physical and mental exertion (Diecke) likewise do not withstand criticism, because with a decrease in active radiation from the sun changes in the blood picture diminished regardless of the physical and mental exertion of the subjects studied.

This disagreement among the European investigators in their interpretation of the cause of functional leukopenias and relative lymphocytoses disappears if these phenomena are considered from the standpoint of solar-terrestrial connections.

Reflection of the Corti-effect and Piccardi's solar hypothesis in the leukocyte picture is explained on the assumption that in spring and autumn the projection of the earth on the sun lies at relatively more active latitudes of the sun, so that in spring and autumn the earth is under more favorable conditions for irradiation by the geoactive emission from the sun than in summer and winter.

The fact observed by the author, that the course of functional leukopenias accurately reflects the fluctuations in solar activity, began to be studied in 1958 by five Italian scientists who accepted the author's conclusions on this matter as valid. They published a special article on this question in an Italian journal (*Geofisica e Meteorologia*, Genova, 1964, 13, No. 3/4, 65-66).

According to the author's data, active solar regions with magnetic characteristics of β γ and γ spots, when the area of the group of spots exceeded 200 millionths of the sun's hemisphere and gave five or more bursts classified at higher than 2 points, had a particularly marked influence on the incidence of functional leukopenias. The author recommends making allowance for the position of active regions, their area, their connection with the radio-emission of the sun, the power and character of magnetic storms, and individual strong emissions from regions not distinguished by their high activity. In his opinion, when considering bursts of activity, attention must be paid also to those observed in the Western hemisphere of the earth, because the effect due to them may be manifested also in the Eastern hemisphere, where no bursts were found, because of rotation of the earth (*Solnechnyye Dannyye*, Akad. Nauk SSSR, 1963, No. 2, 73-76).

The reason why the incidence of functional leukopenias and relative lymphocytoses begins to rise at the beginning of each new solar cycle before the solar index, in the author's opinion, is because of the more energetic activity of the Bartels M-region on the decremental branch and at the minimum of the solar cycle. This phenomenon, first mentioned in the literature by the author on the eve of the minimum of solar cycle XIX was again repeated on the eve of cycle XX, and in the opinion of heliogeophysicists this deserves great attention (*Folia Haematologica*, 1962, 79, No. 4, 401-417).

The author wrote a paper for the 10th International Medical Congress in Italy in 1963 on biological characteristics of the active radiation of the sun as he interprets them. His paper at this congress was read by the director of the Florentine Institute, Professor D. Piccardi (*Minerva Medica*, 1963, 54, No. 38, 40-41). /18

The prolonged parallel course of changes in the leukocyte picture under non-pathological conditions and physical processes on the sun observed by the author in a large number of cases in different geographical regions and at different times conclusively demonstrates the undoubted influence of solar activity on the human organism. By methods similar to those used by the author, heliogeophysicists have established the dependence of climatic variations, hydrological phenomena, fluctuations in the level of the Caspian Sea and great lakes, freezing of the polar seas,

and paleoclimatic changes on solar activity. Solar-terrestrial connections in the troposphere are the foundation of modern heliogeophysics. The study of solar-terrestrial connections in the biosphere has become a cornerstone of the problem of the effect of the sun's active radiation on the human organism.

Particular attention must be paid to the time factor. The leukocyte count today cannot be compared with its value yesterday or tomorrow, because sudden solar flares may cause marked changes in the leukocyte count. The time factor is now such a powerful argument that it cannot be disregarded. The same is also true of bioactive fractions of the solar radiation and of the sun's radio-emission, of cosmic influences, and of many other factors acting on the human organism. These problems have been carefully studied by heliophysicists, but they have been ignored by medical scientists (Solnechnyye Dannyye, Akad. Nauk SSSR, 1960, No. 9).

New methods of observation are appearing. To study the relationship between the leukocyte count and active radiation of the sun, material gathered during prolonged observations conducted in different geographical regions of this planet must be collected and compared. The question of correlation needs to be approached more carefully. For instance, when cases of sudden increase in the number of functional leukopenias in Leningrad are compared with data of the Pulkovskaya Observatory concerning strong solar flares, and no parallel is found between the biological and solar phenomena, it may be concluded that no correlation exists. However, in the Western hemisphere, flares were recorded which caused the responses of the blood picture in Leningrad. For this reason, before concluding that correlation is absent, solar data must be obtained in their full range from international fundamental catalogs of solar phenomena.

It is important to know not only of the emission of solar corpuscles, but also of the velocity of their particles: the higher the velocity of the particles, the greater their biological activity.

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Lack of knowledge of the mechanism of solar-terrestrial connections in biology and medicine in no way interferes with the study of the effect of the sun's active radiation on the organism. The etiology and pathogenesis of many diseases are still unknown, yet physicians treat them, often successfully.

What is the value of the author's investigations? Scientists cannot interfere with the appearance of magnetic storms, the development of sunspots, or the generation of electromagnetic waves, but by making allowance for the effects of these factors on the human body and, in particular, on its blood system, they can correctly interpret deviations observed in the course of several physiological and pathological processes. In some cases, by means of a magnetograph, their adverse effect can be presented by appropriate prophylactic measures (Solnechnyye Dannyye, Akad. Nauk SSSR, 1964, No. 9).

The data collected by the author clearly indicate that the time has arisen for a reexamination of cosmic influences on physiological and pathological processes in the light of advances in heliogeophysics.

SUMMARY

1. Analysis of the incidence of functional leukopenias during the last 45 years has revealed a strict pattern of fluctuations in the leukocyte count under nonpathological conditions. These fluctuations take place as independent but interconnected cyclic processes of an anharmonic character.

2. The strictly regular pattern of these fluctuations is due to coincidence of the phases of cyclic changes in the incidence of functional leukopenias with the fluctuations of solar radiation. This coincidence is clearly visible if changes in the leukocyte count in normal subjects are compared with fluctuations of solar activity. The active radiation of the sun influences the blood cells through the central nervous system, which is highly sensitive to changes in solar radiation.

3. The maximum of the number of functional leukopenias coincides in time with the maximum of solar activity, and its minimum coincides with the solar minimum. The number of functional leukopenias rises sharply after emissions of proton particles, ejected with a velocity exceeding 1000 km/sec from regions with magnetic characteristics of β γ and γ spots, when the area of the group of spots exceeds 200 millionths of the sun's hemisphere and gives five or more flares with a classification higher than two points.

4. Everything which has been said about functional leukopenias applies equally to relative lymphocytoses. Since functional leukopenias are formed as the result of a decrease in the number of neutrophils, the disturbance of equilibrium between the various types of leukocytes in favor of lymphocytes leads to the appearance of relative lymphocytoses.

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5. Coincidence between phases of fluctuation in the leukocyte count under nonpathological conditions with fluctuations in solar activity suggests that functional leukopenias and relative lymphocytoses can be used as specific leukocyte tests of solar activity. These tests are highly sensitive indices of fluctuations in solar activity, supplementing geophysical data on active radiation of the sun.

6. The percentage of functional leukopenias and relative lymphocytoses in northern latitudes is higher than in southern, and this is explained by closeness to the polar auroral zones, where the bulk of the solar corpuscles impinge.

7. These cyclic changes in the absolute and differential leukocyte counts under nonpathological conditions make the concept of stable absolute normal leukocyte counts meaningless. From this standpoint, the normal values of the leukocyte count are relative concepts and, besides age and sex differences, they must also allow for local geographical conditions and significant variations in the active radiation of the sun.

8. The most effective method of investigation of the effects of the sun's active radiation on the blood picture at the present stage of development of the study of solar-terrestrial connections in medicine are by mass observations over many years, including repeated observations, carried out at many different geographical points on the earth by the same method.

9. By introduction of the magnetograph into hospital practice, on the appearance of powerful solar flares, timely prophylactic measures can be taken on behalf of persons reacting acutely to sharp increases in solar activity.

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in This Summary

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